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## TEST METHOD FOR COMBINING AGGREGATE GRADATIONS

When the aggregate gradations for a PCC mixture are sampled and tested individually, the results must be mathematically combined to create a theoretical combined gradation. This combined gradation is based on their relative percent volume in the mixture.

Each individual aggregate gradation shall start with the largest appropriate sieve for that material and shall include all the consecutive smaller sieve sizes through the 75  $\mu$ m (#200) sieve. They shall include: 37.5 mm (1½ in.), 25 mm (1 in.), 19 mm (¾ in.), 12.5 mm (½ in.), 9.5 mm (⅜ in.), 4.75 mm (#4), 2.36 mm (#8), 1.18 mm (#16), 600  $\mu$ m (#30), 300  $\mu$ m (#50), 150  $\mu$ m (#100), and 75  $\mu$ m (#200) sieves.

The following steps outline the procedure to be used to determine this combined gradation:

### **STEP 1**

The percent volume of each of the aggregates is determined from the volume proportions of the mixture design. The relative proportion of each aggregate of the total aggregate is determined by dividing the individual aggregate portion in the mix by the total aggregate portion in the mix.

#### Example:

A mixture design has the following mix proportions by volume:

Cement	0.110
Water	0.150
Air Entraining	0.070
Fine Aggregate (PCC Sand)	0.270
½ inch Intermediate Aggregate (Limestone Chip)	0.100
1½ inch Coarse Aggregate (Limestone PCC Stone)	0.300
<b>Total</b>	<b>1.000</b>

The total aggregate portion is:  $0.270 + 0.100 + 0.300 = 0.670$

The relative percent retained portion for each aggregate by volume is determined as follows:

Fine Aggregate  $(0.270/0.670) = 0.403$   
Intermediate Aggregate  $(0.100/0.670) = 0.149$   
Coarse Aggregate  $(0.300/0.670) = 0.448$

Check the total aggregate relative portions. They should equal 1.000.

$0.403 + 0.149 + 0.448 = 1.000$  (OK)

## **STEP 2**

These volume proportions are then adjusted by the specific gravity of the aggregates, since gradations are based on percent weight retained on each sieve. The proportion retained by weight is determined by multiplying each aggregate's volume proportion by its specific gravity. These weights are then summed to obtain a total weight. The proportion by weight is then determined by dividing each aggregate's weight by the total weight.

Example:

<b>Aggregate</b>	<b>Proportion Volume</b>	<b>Specific Gravity</b>	<b>Weight</b>	<b>Proportion By Weight</b>
<b>Fine</b>	0.403	2.67	1.07601	$(1.07601/2.64912)= 0.406$
<b>Intermediate</b>	0.149	2.59	0.38591	$(0.38591/2.64912 = 0.146$
<b>Coarse</b>	0.448	2.65	1.18720	$(1.18720/2.64912)= 0.448$
<b>Total</b>	1.000		2.64912	1.000

## **STEP 3**

Determine the theoretical combined gradation from the individual gradations. This is done by multiplying the percent retained on each sieve for the individual gradations by the relative portion of the aggregate volumes. Then total the percent retained of each product for each sieve size. This is the theoretical combined percent retained for each sieve. The total of these percents retained should equal 100.0. If the total is off due to rounding, prorate the rounding error.

Example:

### **Coarse Aggregate**

<b>Sieve</b>	<b>% Retained</b>	<b>Relative Volume</b>	<b>Adjusted % Retained</b>
<b>1½ inch</b>	0.0	0.448	0.0
<b>1 inch</b>	1.4	0.448	0.6
<b>¾ inch</b>	23.7	0.448	10.6
<b>½ inch</b>	31.0	0.448	13.9
<b>⅜ inch</b>	24.5	0.448	11.0
<b>No. 4</b>	14.1	0.448	6.3
<b>No. 16</b>	0.7	0.448	0.3
<b>No. 30</b>	0.8	0.448	0.4
<b>No. 100</b>	0.4	0.448	0.2
<b>No. 200</b>	0.2	0.448	0.1
<b>Minus 200</b>	0.8	0.448	0.4

Similar calculations are done for the intermediate and fine aggregates.

#### **STEP 4**

The individual adjusted gradations are summed to get the theoretical combined gradation, percent retained. The theoretical combined gradation, percent passing, may be calculated by subtracting subsequent sieves beginning with 100, as per [I.M. 302](#). The following table shows the calculations:

<b>Sieve</b>	<b>Coarse Aggregate</b>	<b>Intermediate Aggregate</b>	<b>Fine Aggregate</b>	<b>Theoretical Combined Gradation % Retained</b>	<b>Theoretical Combined Gradation % Passing</b>
<b>1½ inch</b>	0.0			0.0	100
<b>1 inch</b>	0.6			0.6	99.4
<b>¾ inch</b>	10.6	0.0		10.6	88.8
<b>½ inch</b>	13.9	3.2		17.1	71.7
<b>⅜ inch</b>	11.0	5.4	0.0	16.4	55.3
<b>No. 4</b>	6.3	4.9	2.0	13.2	42.1
<b>No. 8</b>	0.9	0.4	4.1	5.4	36.7
<b>No. 16</b>	0.3	0.3	5.6	6.2	30.5
<b>No. 30</b>	0.4	0.1	12.9	13.4	17.1
<b>No. 50</b>	0.1	0.2	12.0	12.3	4.8
<b>No. 100</b>	0.2	0.1	3.1	3.4	1.4
<b>No. 200</b>	0.1	0.1	0.2	0.4	1.0
<b>Minus 200</b>	0.4	0.2	0.4	1.0	0.0

The theoretical combined gradations are used in graphically displaying aggregate blends of PCC mixture designs and for plotting control charts to compare target gradation with working ranges of the mixture design.